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THE FRACTAL PROPERTIES OF THE LARGE-SCALE MAGNETIC FIELDS ON THE SUN

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It is a common knowledge that both the solar plasma and the solar magnetic field have a cellular, discrete structure, which is indicative of their possible fractal origin. The questions of fine structuring of the solar magnetoplasma were considered [1], plausible mechanisms of its genesis were suggested, and possibilities of describing its fractal properties were put forward. The existence of a whole hierarchy of sizes of active features in the solar atmosphere has long been established. For example, it is well known that in addition to the granulation (1"-1.5"), such structures as the mesogranulation (8-15"), the supergranulation (30"-40"), giant cells (20°-40°), and supergiant cells (80°-110°) exist on the Sun. The last two features refer to the so-called large-scale organization of solar magnetic fields [2].

The objective of this paper is to investigate the fractal properties of large-scale magnetic fields on different spatial scales.

This study is based on using:

1. Synoptic maps of large-scale magnetic fields compiled by Stenflo [3] from maps of small-scale magnetic fields using the data from the Mt. Wilson observatory (17″ resolution) from 1959 to 1976 and from Kitt Peak (1″ resolution) from 1959 to 1976. The longitudinal-latitudinal grid occupies in the longitude λ the range from 0° to 360° with steps $\Delta\lambda = 10°$ and in the latitude φ from $-90°$ to 90° with 30 uniform areas by the sine of latitude φ.

2. Synoptic maps of large-scale magnetic fields obtained [4] at the Wilcox observatory (180″ resolution) from 1976 to 1998. The longitudinal-latitudinal grid occupies in the longitude λ the range from 0° to 360° with steps $\Delta\lambda = 5°$ and in the latitude φ from $-75°$ to 75° with 30 uniform areas by the sine of latitude φ.

These longitudinal-latitudinal grids were used in calculations in this paper. The method of scaling the variance of temporal and spatial series was used to calculate the fractal dimension of the maps [5]. The method involves calculating the variance $V(s)$ of a given quantity in each cell with area s. As a result of plotting (on log − log coordinates) the dependence of the variance of the function $V(s)$ on the cell size s areas with a linear approximation are identified, where possible, as $V(s) = s^a$ and the coefficients a of this approximation are determined by the method of least squares. The coefficients a are associated with the Hurst exponent $H = a/2$ as they were obtained by testing of model temporal and spatial series with known H. The fractal dimension of magnetic field distribution on given two-dimensional map is $D = 3 - H$, where 3 represents the dimensions of space.

The scaling of the variance of magnetic field strengths using Stenflo's maps and the maps from the Wilcox observatory was investigated by this method

(s=$\Delta\varphi$x$\Delta\lambda$). The study has shown that the spatial distribution of large-scale magnetic fields on the Sun reveals a fractal character. This manifests itself in the power scaling of statistical characteristics of magnetic fields such as the variance. Also, two typical ranges of spatial scales are distinguished, which appear to characterize two systems of solar large-scale magnetic fields organized into giant ($\sim \Delta\varphi$x$\Delta\lambda < (25^\circ \pm 5^\circ)$x $(45^\circ \pm 5^\circ)$) and supergiant cells ($\sim \Delta\varphi$x$\Delta\lambda > (25^\circ \pm 5^\circ)$x $(45^\circ \pm 5^\circ)$). The fractal dimensions of the space of the strength function of magnetic fields show a high degree of their irregularity and alternation on separate synoptic maps. Time variations of the exponents corresponding to the fractal dimension show a cyclic character, which testifies to a change of statistical and associated physical properties of solar magnetoplasma with cycle phases.

References

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